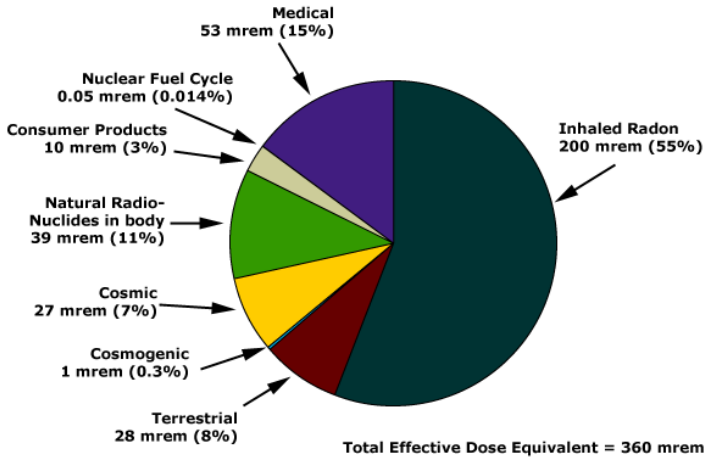
The Facts About Home Radon

Radon has been around since long before mankind appeared on the Earth. More than half of our natural background radiation exposure comes from radon because it is a constituent of the air we breathe. If radon was as deadly as some would have us believe, mankind would have become extinct long ago.

The average natural background radiation dose for Americans from cosmic, terrestrial, radon, and internal sources is generally taken to be ≈300 mrem/year.[1] The radon contribution is ≈200 mrem/year,[1,2,3] as shown in the graphic below from Lawrence Berkeley National Laboratory.[4]



The radon isotope of primary interest is radon-222 (Rn-222), which has a half-life of about 3.8 days. Rn-222 and its short-lived radioactive decay products are the most important contributors to human exposure from natural radiation sources. Rn-222 itself is not a huge health concern, since most inhaled radon exhaled before decaying. However, inhalation of its short-lived progeny (Po-218, Pb-214, Bi-214, and Po-214) attached to aerosol particles are a more significant health concern. The radon radioactive decay byproducts emit both alpha and beta particles as well as gamma rays. While radon itself is exhaled from our lungs with the air we breathe, it is the radioactive decay byproducts which remain in the lungs and produce the radiation dose to lung tissue.

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[1] National Council on Radiation Protection and Measurements (NCRP) Report No. 160, Ionizing Radiation Exposure of the Population of the United States, 2009
[2] Assessment of Variations in Radiation Exposure in the United States, United States Environmental Protection Agency, July 15, 2005
[3] NCRP Report No. 93, Ionizing Radiation Exposure of the Population of the United States, 1987
[4] Lawrence Berkeley National Laboratory, 2011; https://www2.lbl.gov/abc/wallchart/chapters/appendix/appendixd.html

The U.S. EPA assumes an annual 200 mrem radon dose corresponds to a radon concentration of 1 pCi/L.[5] The EPA indoor radon remediation action level of 4 pCi/L then corresponds to an annual radon dose of 800 mrem.

The UNSCEAR 2000 Report[6] is one of the most comprehensive studies on the effects of ionizing radiation, and provides a detailed assessment of both indoor and outdoor global radon doses. The report states that the half-lives of Rn-222 and Rn-220 isotopes as well as their various decay radioisotopes are important for determining the relative dose contributions to the basal cells of the bronchial epithelium (the dose to the pulmonary region of the lungs being of much less significance). Additionally, differences of radioisotope half-lives from Rn-222 and Rn-220 decay produce very different atmospheric distributions of potentially aerosolized decay products.

The report addresses the derivation of absorbed and effective dose coefficients from epidemiological studies and physical dosimetry, global average indoor and outdoor radon concentrations, equilibrium factors that permit radon exposure estimates of potential alpha particle energy concentration from measurements of radon gas concentration, and indoor and outdoor occupancy factors used to calculate total global average annual effective radon doses.

The report also states that due to its very short half-life, Rn-220 is a lesser contributor to human radon exposure since 1) the timeframe for diffusion of the short-lived radioisotope in soils results in some decay to non-gaseous radioisotopes before reaching the soil surface, and 2) the very short half-life results in little travel distance from the origination site to the immediate environment of human beings before decaying to non-gaseous radioisotopes. Nonetheless, while less work has been done to derive an effective dose coefficient for Rn-220 decay due to lack of epidemiological data for lung cancer risk following Rn-220 exposure, the report calculates annual effective doses for Rn-220 decay.

According to the EPA, the average U.S. indoor and outdoor radon concentrations are ≈1.3 pCi/L (48 Bq/m^3) and ≈0.4 pCi/L (14.8 Bq/m^3), respectively, based on an EPA 1991 national residential radon survey.[7]

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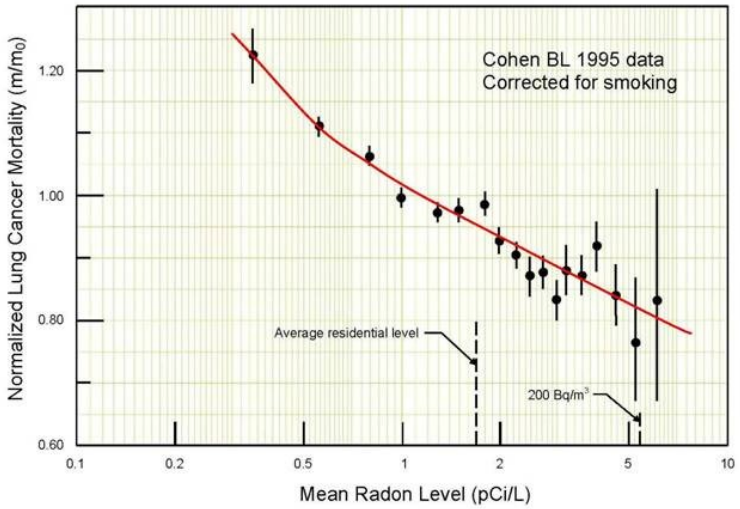
[5] Assessment of Variations in Radiation Exposure in the United States, United States Environmental Protection Agency, July 15, 2005, page 12

[6] Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, Volume 1: Sources

[7] EPA 402-R-92-011, National Residential Radon Survey Summary Report, October 1992 (updated September 2023)

Using the UNSCEAR radon annual effective dose calculation,[8] the U.S. total average annual effective dose is calculated to be 134 mrem. If the indoor radon concentration of 1.3 pCi/L results in a calculated dose of 120 mrem, then EPA assumption of 200 mrem dose corresponding to radon concentration of 1 pCi/L cannot be true. In addition, the indoor radon remediation action level of 4 pCi/L corresponds to an annual radon dose of ≈370 mrem, not 800 mrem.

Furthermore, for an indoor occupancy factor of 0.8[9] the U.S. average annual radon dose of 200 mrem results in average indoor annual dose of 160 mrem. In accordance with the UNSCEAR calculation, this annual effective dose corresponds to an indoor radon concentration of 1.7 pCi/L, which matches the average residential radon concentration in the 1995 indoor radon study[10,11] conducted by University of Pittsburgh physics professor Bernard Cohen, as shown in the graphic below.



In the low concentrations encountered in American homes, radon is not a cause of lung cancer, let alone “the second leading cause,” as claimed by the U.S. EPA. On the contrary, in this setting radon is actually protective against lung cancer. Any attempt to reduce the concentration in homes lowers that protective feature, and leads to a greater, not lesser, probability of developing lung cancer.

The radon controversy should have been terminated with the Cohen indoor radon study. In his study, Dr. Cohen examined homes in 1,601 counties

[8] UNSCEAR 2000 Report, Sources and Effects of Ionizing Radiation, page 107
[9] UNSCEAR 2000 Report, Sources and Effects of Ionizing Radiation, page 105
[10] Cohen, BL, Test of the linear-no threshold theory of radiation carcinogenesis for inhaled radon decay products. *Health Phys.* 1995; 68:157–174
[11] Cohen, BL, Lung cancer rate vs. mean radon level in U.S. counties of various characteristics. *Health Phys.* 1997; 72:114–119

comprising about 90% of the U.S. population. He had hoped to measure how quickly lung cancer rates increase with higher home radon levels. However, what he found was that there were *lower* lung cancer rates in counties having higher average radon levels, and conversely, *higher* lung cancer rates in counties having lower average radon levels. Because this was not the result he was anticipating, Dr. Cohen enlisted a statistician to find possible confounding influences, such as smoking or other carcinogens, that might explain this unexpected and very strong inverse relationship. After examining hundreds of possible confounder combinations, they were unable to identify an alternative explanation for the study findings as illustrated in the graphic above.

Although several scientists have repeatedly tried to refute Dr. Cohen's study, they have been unable to assemble a plausible argument in opposition, and his discovery of radon's protective (hormetic) effect at low levels of exposure has been corroborated by dozens of studies since then. In fact, a 2021 Polish study[12] confirmed that the relative number of lung cancers decreases with increasing radon concentrations up to 200 Bq/m^3 or 5.4 pCi/L.

Studies concluding that low doses of ionizing radiation are harmful either ignore biological reality or distort and/or dismiss it. The "all radiation is harmful" paradigm is a powerful hindrance to scientific objectivity. It has justifiably been called "the greatest scientific scandal of the 20^{th} century" by the former director of the Swedish Radiobiology Society, Gunnar Walinder.[13]

Regardless of the actual radon concentrations and associated radiation doses in American homes, any concern about the potential health effects of indoor radon should be based on actual observed effects as illustrated in the graphic below.[14]

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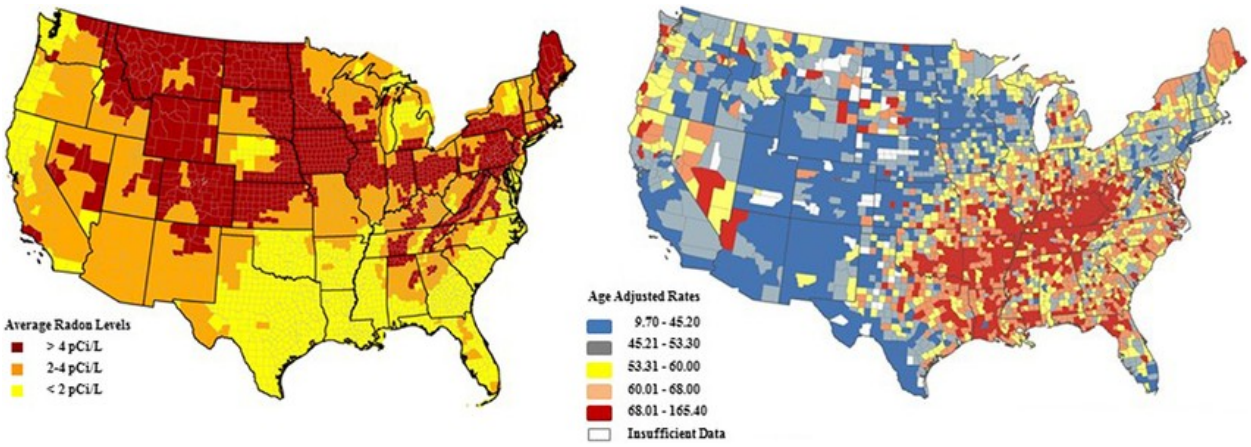
[12] Pylak M, Fornalski KW, Reszczyńska J, Kukulski P, Waligórski MPR, Dobrzyński L, *Analysis of Indoor Radon Data Using Bayesian, Random Binning, and Maximum Entropy Methods*, Dose Response, May 17, 2021

[13] Gunnar Walinder, 1995. *Has Radiation Protection Become a Health Hazard?* (Nykoping, Sweden: Karnkraftsakerhet & Utbildning AB, Swedish Nuclear Training and Safety Center).

[14] Vaiserman, A, Koliada, A, Zabuga, O, and Socol, Y, *Health Impacts of Low-Dose Ionizing Radiation: Current Scientific Debates and Regulatory Issues*, Dose-Response, July-September 2018: 1-27



The map on the left shows EPA predicted average indoor radon levels (EPA Map of Radon Zones, provided with permission of EPA Radiation Protection Division), while the map on the right shows 2000 to 2009 lung cancer mortality rates per 100,000 by county, corrected for smoking (Static Maps, National Community Mapping Institute). If lower lung cancer mortality is associated with higher indoor radon concentration, then radon cannot be the dominant cause of lung cancer in areas of the U.S. having the highest lung cancer mortality rates.

Furthermore, high background radiation areas of the world (e.g., Kerala, India, Guarapari, Brazil, and Ramsar, Iran) show no significant correlation between cumulative radiation exposure and incidence of cancer.

A 2007 report by the International Commission on Radiological Protection[15] concludes there is general agreement that epidemiological methods used for the *estimation* of cancer risk do not have the power to directly reveal cancer risks for doses up to approximately 100 mSv (10,000 mrem). Since the U.S. *annual* natural background radiation exposure from radon is only about 2 mSv (200 mrem), there is no evidence to support any cancer risk estimates from home radon.

In conclusion, low-dose radiation exposures do not inhibit the ability of the body's adaptive protection mechanisms to repair radiation-induced cell damage, and exposure to radon (both indoor and outdoor) does not result in adverse health effects.

[15] ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4)